Investigation of reaction dynamics around the Coulomb barrier for ^{28}Si + ^{116,120,124}Sn systems

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Gaining insight into the dynamics of heavy-ion collisions at sub-barrier energies has been the motivation for numerous experimental as well as theoretical research efforts in the past few decades. One interesting phenomenon observed in this region is sub-barrier fusion enhancement. This sub-barrier fusion has been attributed to the probability of quantum tunneling through a potential barrier. A large enhancement in the sub-barrier heavy ion fusion cross sections over the predictions of One-Dimensional Barrier Penetration Model (1-D BPM) has been observed experimentally [1]. Coupling between the relative motion in the entrance channel with intrinsic degrees of freedom of the participating nuclei and nucleon transfer channels has been invoked to explain the measured fusion excitation functions. The influence of nuclear vibration and deformation has been unambiguously established within the framework of coupled-channels (CC) calculations. However, the role of neutron transfer has been seemingly elusive in most of the cases [2]. In order to ascertain the aforementioned aspects, fusion excitation function measurements have been performed for ^{28}Si + ^{116,120,124}Sn systems using Heavy Ion Reaction Analyzer (HIRA) [3] at Inter University Accelerator Centre (IUAC), New Delhi.

A ^{28}Si pulsed beam with 2 μs pulse separation from the Pelletron accelerator facility was used in the experiment to bombard isotopically enriched ^{116,120,124}Sn targets of thickness $\sim$ 230 μg/cm^2 [4], $\sim$ 215 μg/cm^{2}and $\sim$ 100 μg/cm^2 respectively, fabricated on thin carbon backing of $\sim$ 20 μg/cm^2 using Vacuum evaporation tecnique at the Target lab of IUAC. The fusion excitation function measurements were performed at laboratory beam energies in the range of 88 - 121 MeV ($\sim$ 14% *below to* $\sim$ 15% *above Bass barrier* V_B) at 1.5 MeV steps around the barrier and 2 MeV steps in sub-barrier region. Two silicon detectors were mounted inside the target chamber at 15.5° with respect to beam direction for the purpose of beam monitoring and normalization. A carbon foil of thickness $\sim$ 10 μg/cm^2 was placed 10 cm downstream from the target for re-equilibration of charge states of Evaporation Residue (ER). The ERs were separated by the HIRA and were detected at the focal plane using a two-dimensional position sensitive Multi Wire Proportional Counter (MWPC) with an active area of 150 × 50 mm^2 operated at a pressure of 5 mbar of Isobutane gas. The solid angle of acceptance for the HIRA was kept 5 mSr during the measurements. The ERs were identified through the two-dimensional spectrum of ER energy loss (ΔE) vs ER time of flight (TOF).

Analysis and Results

The coupled-channels formalism has been employed in deciphering the mechanisms that are responsible for the experimentally observed enhancement in fusion cross sections at sub-barrier energies as compared to 1-DBPM

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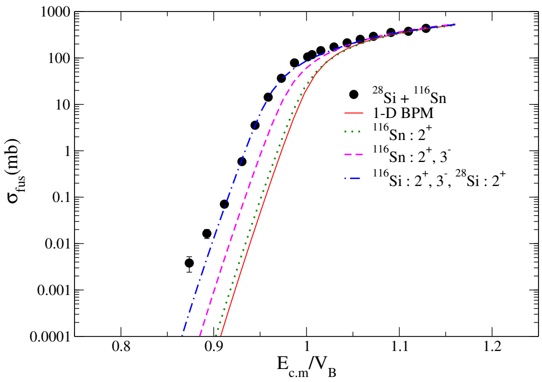

FIG. 1: Experimental fusion excitation function for the ^{28}Si + ^{116}Sn system along with coupled-channels calculations using the CCFULL

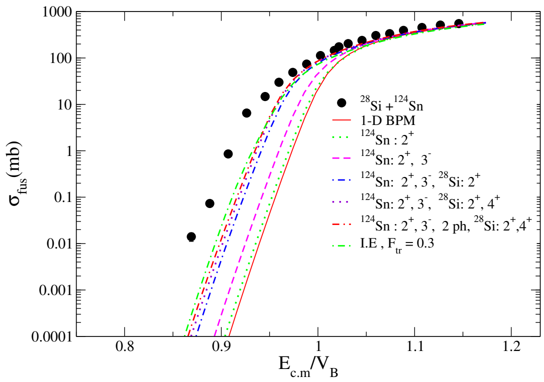

FIG. 2: Experimental fusion excitation function for the ^{28}Si + ^{124}Sn system along with coupled-channels calculations using the CCFULL

calculations. Woods-Saxon parametrization of Akyüz-Winther(AW) potential has been used for coupled channel analysis using CCFULL [5]. The experimental fusion excitation functions for two of the three Sn isotopes viz.^{116,124}Sn along with the CCFULL calculations are shown in Fig. 1 and Fig. 2 respectively. To investigate the role of projectile and target structure effects on fusion excitation functions, the rotational states of ^{28}Si projectile, and vibrational states of the ^{116,124}Sn (2^+ and 3^-) targets are considered in the coupling scheme. It can clearly be inferred from the fusion excitation plots that 3^- state enhances the fusion cross section more than the 2^+ states of the target, implying the stonger coupling to 3^- state. Inclusion of 0^+, 2^+ states of the projectile ^{28}Si further increases the sub-barrier fusion cross section. The fusion excitation function for ^{28}Si + ^{116}Sn has been well reproduced by the CCFULL calculations after the inclusion of the inelastic couplings (rotational for ^{28}Si, and vibrational for ^{116}Sn). However, a similar coupling scheme fails to reproduce the fusion cross section for the ^{28}Si + ^{124}Sn system even after the inclusion of one pair transfer channel coupling along with projectile and target inelastic couplings as shown in Fig. 2. An examination of the ground state Q-values of the three systems shows that the ^{28}Si + ^{116}Sn system has only 2n pickup channel with positive Q-value, while ^{28}Si + ^{120} has 2n-4n, and ^{28}Si + ^{124}Sn reaction has positive Q-values for 2n to 6n pickup channels. These observations divulge the importance of multi-neutron transfer channel couplings in CC calculations. Further data analysis is under process to discern the dynamics of fusion excitation function in the sub-barrier region. Detailed results and analysis will be presented during the Symposium.

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